

## **The Flood Routing Problem for the Kissimmee Basin**

When modifications to water control operations within the Kissimmee Basin or other physical alterations are considered, they must be evaluated for satisfactory performance under flood event conditions. Flood event routings must be simulated in order to determine if the modifications will satisfy strict flood protection levels of service established in the basin. Below, the significant modeling issues and challenges to flood event simulations in the Kissimmee Basin are summarized.

1. The reservoir routing problem: Upstream discharges must be kept within the limits of what the downstream receiving water bodies can accept:

Upper Basin has a firm capacity of 3,000 cfs and a maximum capacity of 11,000 cfs—this means that discharges from S-65 cannot exceed 3,000 cfs while the Lower Kissimmee Basin is experiencing flooding, and can exceed 3,000 cfs up to a maximum of 11,000 cfs provided the S-65 discharge combined with local flows in the Lower Kissimmee Basin do not cause flooding beyond prescribed levels.

To further explain how operations must be modeled to achieve this real-world objective, consider the routing of a flood event through the Lower Kissimmee Basin. Local inflows reach the river and floodplain at different points along the river and combine into one or more flood waves along the river and floodplain. On top of this, if the Upper Kissimmee Basin needs to make discharges, it has the right to discharge any amount up to the firm capacity of 3,000 cfs. This flow is also added to the Lower Basin flows. These two flows will result in flood stages along the river that may or may not exceed expected flood stages for the magnitude of the flood event (Expected flood stages means: a five-year event or one with a 20 % chance of annual occurrence should not exceed the “five-year floodplain” that is established as part of the project lands; and the 100-year or the 1% event should not exceed the “hundred-year floodplain;” and so forth for all flood events magnitudes.) Once the flooding in the Lower Kissimmee Basin falls below this expected flood stage, the discharge from the Upper Basin can be increased above 3,000 cfs to a maximum of 11,000 cfs to fill the difference or “slack” that would otherwise be experienced in the Lower Basin. The discharge from the Upper Basin cannot ever exceed 3,000 cfs if that discharge would occur in a way (at a time) that would cause stages anywhere in the Lower Basin to exceed the expected flood stage.

Modeling flood events in this basin require that the Upper Basin/Lower Basin operations in the simulation achieve the above balance.

Additionally, routing flood waters from pool to pool along a channel or from lake to lake in the Upper Basin can be limited to the discharges physically possible based on the local hydraulics or on discharges that satisfy the operational goals among the lakes and channel reaches. Sometimes, when everything is flooded to excessive levels, full design discharges may be made everywhere to the extent that local hydraulics will allow them. However, when the flood event is subsiding, operational decisions will be interjected so

that a flooded area lying upstream of a more excessively flooded area may not discharge at the full design level in order to allow the downstream area to recover from excessive flood levels as quickly as possible, then both areas can return to normal levels as soon as possible.

Modeling these channel and lake systems must simulate the operational decisions that will reduce discharges as necessary when the system is recovering from the flood event.

2. The hydraulic routing problems at C&SF structures: The water control structures in this basin are submerged ogee spillways topped with vertical lift gates and discharges are generally significantly influenced by tailwater stages. There are a few structures that are gated culverts which have low flow rates and in some cases serve as divide structures that can be used to balance or fine-tune water levels, but are not significant in flood event routings. These gated culverts are not the focus of this discussion. Modeling the submerged ogee spillways require that simulations properly consider the structure hydraulics and operational limitations that exist with these spillways.

Discharge at these spillways are always driven by a desired discharge that would satisfy operational goals upstream or downstream of the spillway and/or within the broader system of lakes and channels as described above. Desired discharge is met if physically possible within the hydraulic limitations of the spillway. To determine the hydraulic limitations of a spillway, the upstream and downstream water levels as well as the gate opening must be known. The downstream water level will not vary much from one time step to another if the structure discharges directly into a lake or large reservoir; however, in the Kissimmee basin, usually, spillways discharge into a channel that is the connecting link to the lake or reservoir. The tailwater in this channel is usually time varying and requires that an unsteady flow approach be used to predict the tailwater for calculation of the spillway discharge.

Additionally, the gate opening is restricted to a “maximum allowable gate opening” which is based on not reaching erosive velocities in the channel downstream of the structure apron. There is a unique maximum allowable gate opening for every combination of headwater and tailwater. For most headwater and tailwater combinations, the maximum allowable gate opening will require that the gate restrict the flow over the ogee crest. For some headwater and tailwater combinations, the maximum allowable gate opening will allow the gate to be raised fully out of the water where the structure hydraulics are “uncontrolled.”

In the Kissimmee Basin, the low relief means that in most flow conditions, tailwater is a factor in discharge. Tailwater stages with respect to headwater stages can be used to classify structure hydraulics as “free,” “partially submerged,” or “highly submerged.” Different discharges result from different degrees of submergence as a result of the damping effect of the tailwater.

The combination of gate openings and tailwater submergence represent four primary flow regimes:

- A. Controlled-Free: controlled flow (gates in water) with free discharge (tailwater submergence is low)
- B. Controlled-Submerged: controlled flow (gates in water) with submerged discharge (the degree of tailwater submergence is a factor in discharge)
- C. Uncontrolled-Free: uncontrolled flow (gates are clear of water surface) with free discharge (tailwater submergence is low)
- D. Uncontrolled-Submerged: uncontrolled flow (gates are clear of water surface) with submerged discharge (the degree of tailwater submergence is a factor in discharge)

Again, for each time step in a flood event simulation, a model must assess the desired discharge for operational goals, locally and across the basin and determine if the desired discharge or what fraction can be achieved within the hydraulic limitations of the spillway. The hydraulic limitations of the spillway are a function of headwater and tailwater stages and a related maximum allowable gate opening. The tailwater stage must be determined from the solution of the unsteady flow problem.